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A Continuous Explosion Puffing System

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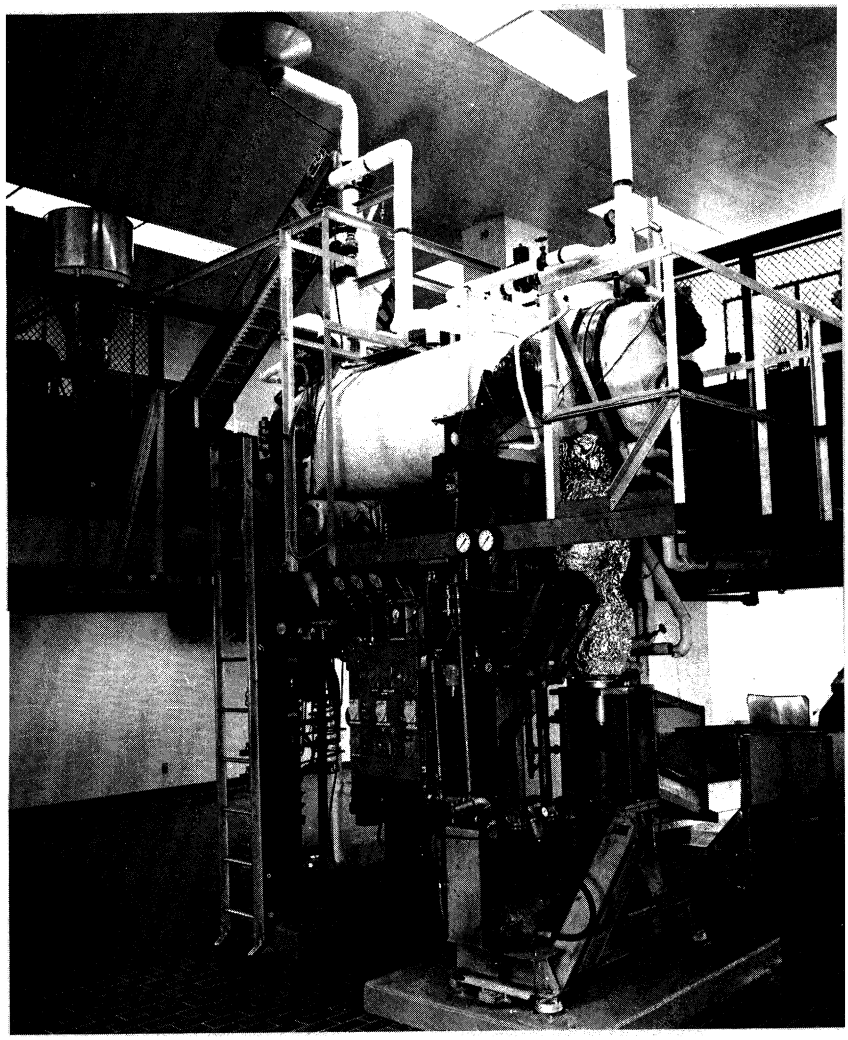

Fig. 1—**CONTINUOUS EXPLOSION PUFFING SYSTEM** *at the ARS-USDA Eastern Regional Research Center*

□ EXPLOSION PUFFING of fruits and vegetables to produce quick-cooking dehydrated products has received wide publicity (Cording et al., 1962; 1963; 1964; Eisenhardt et al., 1962; 1964; 1967; Heiland et al., 1965; Stabile et al., 1971; Sullivan et al., 1963; 1965; 1977). In this process, food pieces are air-dried in a conventional manner to 15-35% moisture, depending on the commodity. By exposure to 10-70 psig steam, these pieces are quickly heated and their remaining water is superheated relative to atmospheric pressure. When the pieces are suddenly discharged to the atmosphere, the rapid pressure drop causes some of the water within the pieces to flash into steam. The escaping steam causes channels and fissures thus imparting a porous structure to the pieces. This facilitates rapid finish drying and quick rehydration of the fully dried product. The structure is retained after drying.

In all earlier work on puffing at the ARS-USDA Eastern Regional Research Center (ERRC), food pieces were heated under pressure in a batch gun and then puffed by expelling the pieces from the gun. Heating and puffing are inseparable in a conventional batch gun. Separating these two major functions in a continuous system (Cording, 1968) results in better process control, improved product quality, and reduced labor costs.

A continuous explosion puffing system (CEPS) which has high output and yields quick-cooking dehydrated fruits and vegetables of good quality is described below.

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CEPS EQUIPMENT & OPERATION

The CEPS, as pictured in Figure 1, and shown schematically in Figure 2 consists of a number of major components: a volumetric feeder with a hopper, an inclined feed conveyor, a feed chamber, a steam jacketed heating chamber, a discharge chamber, a discharge piston (Heiland et al., 1969), and a removal system.

The three subassemblies that are unique to the continuous system and accomplish the three most important functions of feeding, heating and discharging are: the feed chamber between valves 1 and 2; the heating chamber between valves 2 and 3; and the discharge chamber between valve 3 and the discharge piston. Feed chamber and discharge chamber are automatically pressurized and depressurized in sequence with the operation of the valves. Depressurization of the discharge chamber, however, occurs as an explosive discharge.

Depending on the commodity being puffed, processing conditions will vary, but the operating sequence of the system remains the same.

The volumetric feeder continuously drops partially dried pieces of fruits or vegetables at a preset rate into the feed conveyor. From here, a trough-type, cleated conveyor belt transfers them into the top of the feed chamber. While

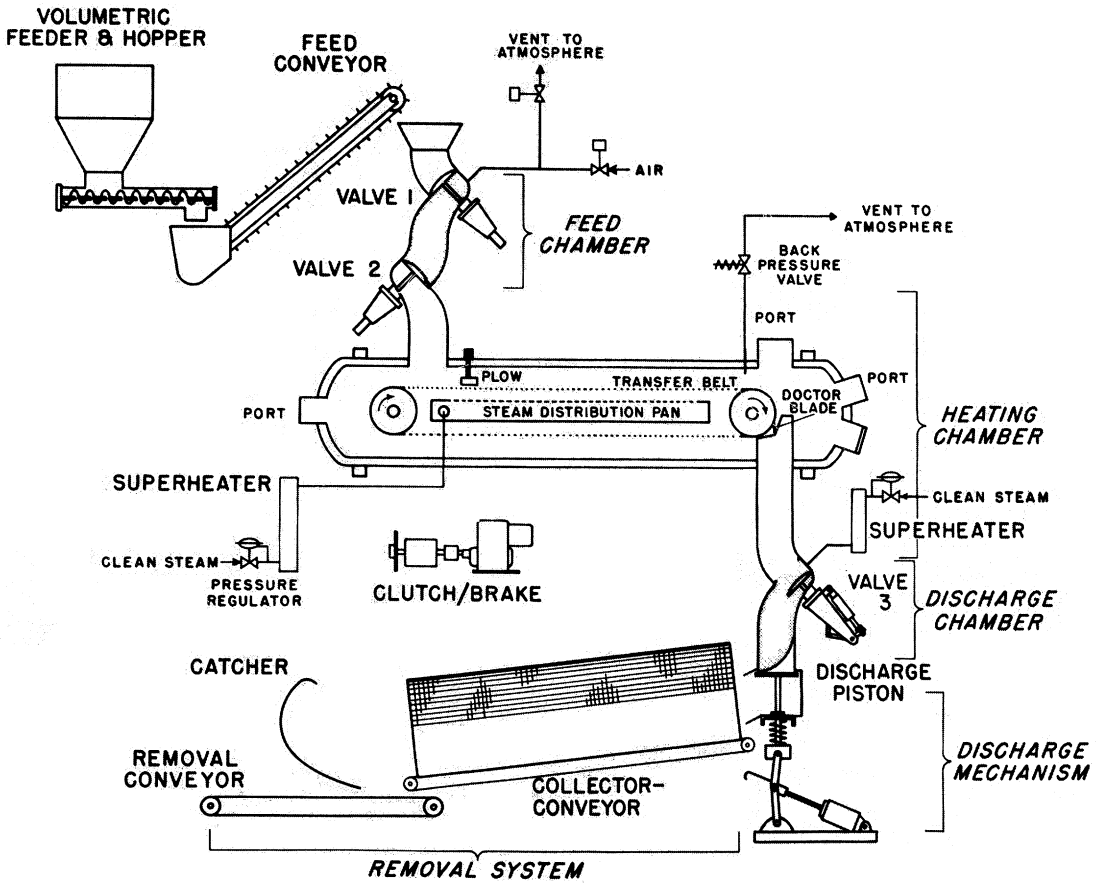

Fig. 2—**MAJOR COMPONENTS** *of the continuous explosion puffing system are identified in this schematic diagram*

valve 2 is closed, the pieces are transferred into the feed chamber (which at this time is open to the atmosphere), valve 1 closes, and the feed chamber is pressurized. Immediately before the closing of valve 1, the feed conveyor stops momentarily. This prevents pieces of food from getting caught in the nip of valve 1 when it closes. At the same time a short blast of air blows the valve face clean.

After pressurization of the feed chamber, valve 2 opens and the food pieces drop onto the heating chamber's transfer belt. Valve 2 closes, the feed chamber is vented to the atmosphere and the feed cycle is repeated.

After the food pieces are deposited on the transfer belt, they are distributed across its width with the aid of a stationary plow. The plow is adjustable and controls the bed depth on the belt. Clean superheated steam is introduced into the chamber below the belt. The steam is sparged through the entire length and width of the transfer belt by means of a pan with a stainless steel screen on top. Steam passes upward through small openings in the belt and through the food pieces as they are conveyed toward the discharge end. At the end of the belt, the food pieces drop off onto the discharge piston. Any pieces that adhere to the belt are removed by a spring loaded doctor blade. To prevent food pieces getting caught in valve 3's nip or sticking to the valve face, they are fed into the discharge chamber only when valve 3 is open. This is accomplished by means of a clutch-brake mechanism which automatically drives or stops the belt.

After valve 3 is closed, the food pieces in the discharge chamber are explosively blown out into a collector-conveyor as the discharge piston is accelerated downward. This accomplishes the sudden discharge to the atmosphere. After one second, the discharge piston is closed, the discharge chamber pressurized, valve 3 opens, the transfer belt starts and the discharge cycle is repeated.

The discharged, puffed product is accumulated in the collector-conveyor and removed by another conveyor for final air drying.

NOVEL DESIGN CONCEPTS

The CEPS incorporates a number of novel design concepts. Many of these have evolved through practical experience with a batch gun (Heiland, 1967) and an earlier attempt to develop a continuous system by employing a large commercially available rotary valve to which was attached a discharge mechanism (Heiland et al., 1969). CEPS was developed to avoid sliding sealing surfaces in contact with the food pieces and to minimize condensation. The latter was encountered in both units previously studied. Other innovations provide for separate and independent control of steam pressure, temperature and rate of steam flow in order to achieve even heating of the food pieces, essential

for good uniform puffing. A pressure regulating valve at the steam inlet in combination with a back-pressure valve at the steam exit of the heating chamber are inexpensive and effective means for controlling steam pressure and flow. Initial steam inlet temperature is controlled by two electrical superheaters. By selecting the steam pressure in the jacket of the heating chamber substantially above the processing pressure, the resultant superheat condition allows observation of the chamber interior through three strategically located vision ports. Small openings in the transfer belt tend to provide an even steam flow through the bed of food pieces.

CEPS was also designed to prevent discharging food pieces from impinging on a lid or an equivalent surface. This design was brought about from the study of discharge patterns from a batch gun. During batch operation a substantial percentage of the discharging food pieces become damaged by impinging on the hinged lid of the gun before the lid swings out of the path of the discharging pieces. The discharge piston was designed so that it looks like a cupped hand pointing upward (Fig. 2). When this piston is accelerated downward and the explosive discharge occurs, food pieces are blown directly into the collector-conveyor. The hot, thermoplastic pieces are thereby cooled, permitting subsequent conveying without damage.

In order to accomplish the required sudden discharge to the atmosphere and to minimize the effect of different discharge chamber pressures on the rate of piston opening, a firing spring is employed. The heavy firing spring releases its stored energy at the start of the explosion discharge and helps to overcome the piston's inertia. This—combined with the pressure of the steam inside the discharge chamber—results in a fast opening of the discharge piston.

The primary control of the functions of CEPS (Fig. 2) is provided by two cam shafts (not shown) which operate six pneumatic valves and four limit switches. Cam shaft 1 governs the following functions: Open and close valve 1, open and close valve 2, pressurize and exhaust feed chamber, short air blast to top of valve 1; and momentarily stop the feed conveyor as valve 1 closes. Cam shaft 2 controls the opening and closing of valve 3, the opening of the discharge piston and the stopping and starting of the transfer belt.

SAFETY OF SYSTEM

Safe operation of this complex system is insured by a number of features inherent in the basic design concept. First, the jacketed heating chamber was designed and constructed according to section 8, division 1 of the American Society of Mechanical Engineers code for unfired pressure vessels. Second, unless the pressure below each valve is within 5 PSI of that above, the feed valves 1 and 2 cannot open. Third, valve 3 is prevented from opening if the discharge chamber below is not pressurized. And fourth, no explosive discharge, e.g., the opening of the discharge piston, can be initiated unless valve 3 is in the closed position. Should any malfunction occur, the operation stops and an alarm is sounded.

CAPACITY OF THE SYSTEM

The system was designed for and has been operated at a capacity of 1000 lb/hr of ⅜" potato dice at 25% moisture. Assuming a solids content of 20% and average peeling losses, then one CEPS unit has sufficient capacity to puff the output of a dehydration plant having an input of 3 tons of raw potatoes per hr. When operating with a 12 sec discharge cycle, each explosive discharge would average 3.3 lb. At this stage of development, it is indicated that CEPS requires 750 lb/hr of clean processing steam at 80 psig supply pressure, superheated electrically to 425°F and about 300 lb/hr regular steam at 120 psig supply pressure. Including the superheaters, electrical requirements are 30 KW. If 300 psig steam is available to provide the superheat, only 3 KW are required. To operate the four air cylinders, the clutch-brake and the pneumatically operated control valves, 50 SCFM of compressed air at 90 psig supply pressure is required. An additional 50 SCFM of oil-free compressed air at 80 psig is required to pressurize the feed chamber.

Papers describing processing conditions for various commodities and cost studies will be issued by this Laboratory as these data become available. Detailed construction drawings of CEPS are available free of charge by writing to the authors.